PROVIDING ENHANCED HAPTIC FEEDBACK EFFECTS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of co-pending U.S. patent application Ser. No. 09/669,029, entitled "Controlling Haptic Sensations for Vibrotactile Feedback Interface Devices," filed Sep. 25, 2000 by Goldenberg et al., which claims the benefit of U.S. Provisional Application No. 60/156,354, filed Sep. 28, 1999, entitled, "Controlling Force Sensations for Vibrotactile Feedback Interface Devices," and which are incorporated herein by reference in their entirety.

BACKGROUND OF THE INVENTION

[0002] The present invention relates generally to interface devices for allowing humans to interface with computer systems, and more particularly to low-cost computer interface devices that allow the user to provide input to computer systems and allow computer systems to provide tactile feedback to the user.

[0003] A user can interact with an environment displayed by a computer to perform functions and tasks on the computer, such as playing a game, experiencing a simulation or virtual reality enviromnment, using a computer aided design system, operating a graphical user interface (GUI), etc. Common human-computer interface devices used for such interaction include a mouse, joystick, trackball, gamepad, steering wheel, stylus, tablet, pressure-sensitive sphere, remote control, or the like. Typically, the computer updates the environment in response to the user's manipulation of a manipulandum or user object such as a joystick handle or mouse, and provides visual and audio feedback to the user. The computer senses the user's manipulation of the user object using sensors provided on the interface device.

[0004] In some interface devices, haptic feedback is also provided to the user. These types of interface devices can provide physical sensations which are felt by the user manipulating the user object of the interface device. One or more motors or other actuators are coupled to the device housing or manipulandum and are connected to the controlling computer system. The computer system controls forces output by the actuators in conjunction and coordinated with displayed events. The computer system can thus convey physical force sensations to the user in conjunction with other supplied feedback as the user is grasping or contacting the interface device or manipulatable object of the interface device.

[0005] In many haptic feedback devices, the haptic feedback takes the form of vibrations, jolts, or pulses output on the housing or manipulandum which are experienced by the user, referred to as "tactile" sensations herein. For example, many gamepad devices include a spinning eccentric mass that creates inertial vibrations on the housing or object. Other devices, such as the I-Feel Mouse from Logitech Corp., provide inertial vibrations using a linearly-moving mass. Still other devices may vibrate a housing or object by impacting or directly moving the housing or object with the actuator.

[0006] One problem with current haptic feedback devices is that tactile sensations output to the user tend to be more effective in particular frequency ranges and less effective in other frequency ranges. For example, vibrations output on the housing by an inertial haptic feedback device often feel strong to the user at higher frequencies of vibration, but often feel less strong to the user at lower frequencies. In linearly-moving mass embodiments, for example, this is due to the inertial mass moving slower for lower frequency vibrations, so that the mass does not accelerate as much and causes tactile sensations that feel less strong. In addition, the mass might be pressed against the limits of its range of motion during most of the cycle time of the vibration, providing less force to be felt by the user.

[0007] Another problem with moving mass haptic feedback devices is that combining commanded effects may cause the mass to oscillate about a point close to an end of travel of the mass. This may cause the mass to hit the end of travel before it has completed the desired oscillation, thus clipping the output sensation and reducing its fidelity. In addition, output forces may be reduced in strength when the mass operates near an end of travel due to a physical spring coupled to the mass, since such spring resistance is strongest near the end of travel.

SUMMARY OF THE INVENTION

[0008] The present invention is directed toward features in an interface device to provide enhanced tactile sensations to a user of the device. In devices having inertial tactile forces, high frequency waveforms are used to convey low frequency content, thereby providing stronger tactile effects to the user.

[0009] More particularly, a method for providing tactile sensations using an inertial actuator in an interface device includes receiving a commanded low frequency at which to output a tactile sensation to a user of the interface device, determining a higher frequency, e.g. a frequency at which the inertial actuator outputs high strength tactile sensations as felt by the user, and combining the low frequency with the higher frequency to provide a resulting signal used to output a tactile sensation at the higher frequency, the tactile sensation conveying the commanded low frequency to the user. One example actuator device provides an actuator coupled to a flexure, where an inertial mass is linearly oscillated to output the tactile sensations. The host computer and/or a local device controller can generate and combine the waveforms as described.

[0010] In one embodiment, the combining may include providing multiple bursts of a higher frequency signal approximately at the low frequency to control the inertial actuator to output the tactile sensation. The tactile sensation conveys the commanded low frequency to the user. The higher frequency can be one at which the inertial actuator outputs strong tactile sensations as felt by the user and is preferably high enough so as to cause the user to feel each of the bursts as a single pulse. The higher frequency can be approximately at a resonance frequency of a mechanical actuator system of the interface device.

[0011] In another embodiment, the combining may include creating a waveform having the higher frequency, the waveform having an amplitude that varies according to the commanded low frequency. For example, the combining can be adding a waveform having the commanded low frequency to a waveform having the higher frequency. Or,